BIOLOGICAL SURVEY OF THE GRAND RIVER AND ITS TRIBUTARIES

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Minister

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Deputy Minister

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OF THE

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1966

by
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SUMMARY AND CONCLUSIONS

A general biological survey of the Grand River and its tributaries was carried out in June, 1966, to provide an indication of the degree of contamination of the watercourse by industrial, sanitary and combined wastes. A total of 61 stations were examined. Collections of bottom fauna, fish and water were obtained, whenever possible from each of the sampling locations.

Both biological and chemical parameters showed that Canagagigue Creek was extremely polluted by toxic industrial wastes and considerable organic matter. Toxic components present in Canagagigue Creek were indicated by an impoverished bottom fauna and the complete absence of fish between Elmira and the tributary stream at West Montrose. Some improvement was evident at the mouth of the creek below dilution from this same tributary. Following initial dilution, contaminated water from Canagagigue Creek had not affected the bottom fauna of the Grand River adversely, but seriously limited the variety of fish fauna present.

While bottom fauna communities were not seriously altered throughout Conestoga River, chemical parameters provided evidence of organic contamination from Station C1 to C4.

Moderate impairment of water quality was evident at the mouth of Alder Creek, a tributary of the Nith River to which rendering wastes are discharged. On the Nith River itself, no evidence of impaired water quality was provided by the bottom fauna or fish communities at 10 stations.

The Upper Grand River between Dundalk and Bridgeport generally contained water of satisfactory quality; however, localized impairment was evident below Dundalk and Fergus.

Unlike the localized enrichment of the Upper Grand River, the entire river between Bridgeport and Brantford was moderately enriched. A depression in the variety and

abundance of pollution-intolerant macroinvertebrates, dominance of the fish communities by coarse fish (suckers and carp) and development of a luxuriant growth of filamentous green algae demonstrated the high degree of organic enrichment and resultant fertilization of the waters of the Grand River between these two centres.

Moderate to heavy pollution was evident from Brantford downstream to Caledonia. Undesirable concentrations of nutrients were present and bottom fauna were altered towards fewer taxa and increased numbers of pollution-tolerant organisms. Biological data indicated that water of satisfactory quality was present between Caledonia and Dunnville but below Dunnville, the fauna provided evidence of considerable organic enrichment. No improvement was evident at Port Maitland at the mouth of the Grand River.

Qualitatively, the present survey demonstrated that the Lower Grand River supports a variety of valuable sport fish species including: walleye, pike, brown bullhead, smallmouth bass, largemouth bass and rock bass.

Water quality of the Speed River from Guelph to its confluence with the Grand, was examined and reported by the Biology Branch in 1965. This earlier survey revealed the impaired water quality of the Speed and Eramosa rivers within Guelph and gross organic contamination below Guelph and Hespeler. Only partial recovery was indicated approximately 9 miles below Guelph and impaired water quality prevailed throughout the remainder of the river below Hespeler. The adverse effect of nutrient-rich waste discharges in promoting excessive production of filamentous algae was apparent throughout most of the lower river.

RECOMMENDATIONS

1) The need for improved water quality in Canagagigue Creek is apparent. Efforts to determine the toxic component or components present in the wastes from Uniroyal 1966 Limited

should be intensified to ensure the earliest possible improvement of water quality in the downstream reaches of the creek.

2) Industrial wastes from Biltmore Hats Limited, Hart Chemicals Limited, Matthews Wells Limited and Standard Brands Limited should be directed to the Guelph sewage treatment plant. Trunk sewers have been extended by the city to achieve this goal. Further delay by the industries involved is inexcusable.

3) An effective program for treatment of sanitary and industrial wastes is required to bring an end to the periodic fish kills that have been reported from the Speed River below Hespeler.

4) More specific biological studies should be undertaken to define more clearly the nature and extent of water quality impairment which was indicated downstream from Dundalk and Fergus, throughout the Middle Grand River, below Brantford and Dunnville, and in Alder Creek downstream from Tend-R-Flesh Limited.

5) This study has indicated the presence of a valuable fisheries resource in the Lower Grand River. Future municipal and industrial pollution abatement programmes should be designed to ensure maintenance and future improvement of these fish communities.

6) Data on the present and projected waste loadings and waste assimilation capacities for the Grand River are currently being assembled by the Commission. This information, in addition to more specific biological evaluations and the establishment of a nutrient budget for the river, will be required to develop an integrated waste control program for the watershed that will take into account immediate and future aesthetic and recreational needs.

7) Deteriorations of the Grand River by growths of filamentous algae will continue to be a problem until waste

treatment and land use techniques are developed to minimize inputs of fertilizing elements. Continued emphasis must be placed on the need for research related to both the interpretative and remedial aspects of the enrichment problem.

BIOLOGICAL SURVEY OF THE GRAND RIVER - 1966

INTRODUCTION

Domestic and industrial wastes may alter the physical, chemical and biological properties of the receiving stream. In the past, considerable effort has been expended to provide a basic understanding of the chemical and micro-biological conditions of the Grand River resulting from man-made pollution. However, while considerable public concern has been expressed regarding the effects of pollution on the macrobiota and recreational potential of the river, to date only a limited amount of technical data has been amassed. This general biological survey of the Grand River was performed to describe the biological conditions of the river and to relate these conditions to the general health of the watercourse. In addition, the data collected will provide an excellent basis for detecting future changes in water quality.

Major emphasis will be placed on the invertebrate communities. These are altered by pollution and the fact that they reflect adverse environmental conditions over a period of several months prior to the survey makes them valuable in the assessment of water quality. Normal aquatic communities contain a variety of organisms but relatively few representatives of any single taxum. Communities associated with organic pollution are composed typically of a large number of a small variety of organisms, while aquatic communities which are exposed to toxic wastes are reduced both with respect to numbers and species. These principles will be used in this report to assess the water quality of the Grand River and its tributaries.

GENERAL DESCRIPTION OF THE GRAND RIVER AND TRIBUTARIES

The Grand River drainage basin is comprised primarily of heavily-utilized agricultural land. Supplying the needs of the rural population are approximately 40 strategically located communities, villages, towns and cities. Intensified industrial development has occurred in the major cities along the main branch of the river. In the future, a steady growth of industry and urban development, as well as increased agricultural productivity are anticipated.

The Grand River Watershed occupies 2,600 square miles of land in the Lake Erie Drainage Basin. The main branch of the Grand rises in the swampy plateaus near Dundalk, from whence it flows 180 miles in a general southerly direction to its mouth at Port Maitland on Lake Erie. Flow in the main branch is augmented by its tributaries which include the Conestogo, Nith and Speed rivers as well as the smaller Boston, McKenzie, Fairchild, Whiteman, Big, Irvine and Canagagigue creeks.

Upstream from Brantford, the main branch and its tributaries flow in glacial spillways, whereas the river in the flatter region below Brantford has made its own channel across the oldlake plain. Consequently, the physical characteristics of the river above and below Brantford are quite dissimilar. The northern portion of the river drops 1180 feet in 115 miles through alternating riffles and pools, whereas, the lower section (below Brantford) falls less than one foot per mile and consists entirely of deep, slow-moving water.

The main branch of the Grand from its origin near Dundalk downstream to Bridgeport flows successively through Grand Valley, Waldemar, Fergus and Elora, receiving from its tributaries the drainage of the Irvine, Canagagigue and Conestogo sub-watersheds. Sanitary wastes from the aforementioned municipalities constitute the main source of

pollution entering the Upper Grand River. While no major industrial wastes are discharged directly to the Upper Grand, wastes from Uniroyal 1966 Limited find access to this portion of the river through Canagagigue Creek. Twelve locations (G2 to G12, see Fig.4) were examined along the Upper Grand River.

The Middle Grand River, between Bridgeport and Brantford, passes through Kitchener, Waterloo, Breslau, Preston, Galt, Glen Morris and Paris, receiving from its principal tributaries the drainage of the Speed and Nith spillways. Both household and mixed industrial wastes are discharged into the Middle Grand River. Stations G13 to G20 (Fig.5) were examined along this stretch of the river.

The Lower Grand continues through Brantford, Caledonia, Cayuga, Dunnville and Port Maitland, receiving discharges from the relatively minor tributaries of Boston, McKenzie, Fairchild and Big creeks. Both sanitary and mixed industrial wastes enter the Lower Grand River. Stations G20 to G31 (Fig.6) were examined along this lower portion.

The first tributary of significance downstream from Dundalk is Canagagigue Creek. From a headwater elevation of 1500 feet, the creek falls 450 feet in a distance of 12 miles to its merger with the Grand at a point 10 miles north of Bridgeport. The community of Floradale and the town of Elmira are the only centres of population on the watershed. Stations Ca1 to Ca13 (Fig.1) were examined along Canagagigue Creek.

Four miles downstream, the second tributary of significance, the Conestogo River, merges with the Grand. From a headwater elevation of 1530 feet, the river drops 520 feet in a distance of 40 miles. The Conestogo River flows consecutively through Arthur, Drayton, Glen Allen, Hawkesville, St. Jacobs and Conestogo. Both sanitary and industrial wastes enter the Conestogo River. Water quality was examined at six locations (Stations C1 to C6, see Fig.2) on the Conestogo tributary.

The Speed River flows through Guelph and Hespeler and joins the Grand at Preston. The water quality of the Speed River has been outlined in a recently published report of the Biology Branch of the Commission. Therefore, no further examination was attempted in connection with the survey now being reported.

The final tributary of significance, the Nith River, joins the Grand River at Paris. From a general elevation of 1320 feet, the Nith River falls 510 feet in 72 miles. Communities in the Nith River watershed include Milverton, Millbank, Wellesley, New Hamburg, Plattsville, Haysville, New Dundee, Petersburg, and Ayr. Two tributaries of the Nith receive significant waste discharges. Baden Creek is the receiving stream for milk wastes from a cheese factory at Baden and Alder Creek is the recipient of wastes from a poultry processing firm at Petersburg. A total of 11 locations (N1 to N11, see Fig.3) were examined along the Nith River. Station N8 was located on Alder Creek but no samples were obtained from Baden Creek.

METHODS

The main survey was carried out in June, 1966. Four additional locations (Ca6 to Ca9) on Canagagigue Creek were examined on September 8, 1966. Stations were selected to provide biological data from above and below all potential sources of sanitary or industrial discharges and similarly above and below the confluence of all the major tributaries of the Grand.

Sampling procedures varied considerably. The method employed at any given station was determined following a visual inspection of the river at the designated location. Bottom fauna and fish were sampled as follows:

Bottom fauna

Bottom fauna at stations Ca1 to Ca13 on the Canagagigue Creek and stations G10 and G11 on the Grand River above and

below the confluence of the Canagagigue with the Grand were collected from a 30-minute timed quantitative sample. A 20-mesh (per inch) sieve was used to obtain representative bottom fauna from all micro-habitats present at each sampling location. Wherever possible, bottom fauna at the remaining stations were collected from a 15-minute qualitative sample. However, if the selected site was characterized by deep, slow-moving water rather than riffles, an Ekman or Petersen dredge was employed to secure samples of the bottom sediments and the macroinvertebrates contained within these sediments.

Fish

Fishing techniques varied considerably from the headwater riffles to the deep pools at the mouth of the river. Electro-fishing gear was employed wherever possible to sample the fish communities of Canagagigue Creek. A variety of beach seines were employed to sample the remaining stations. The range of nets employed included a 12' straight seine for sampling the shallow, swift-moving upper reaches to a 100' bag seine for sampling the deep, slow-moving lower reaches of the river. Weed cover, current and substrate limited the effectiveness of the sampling effort. No data on the fish communities at stations G17, G18, G30 and G31 could be obtained.

Water samples

A single grab sample of surface water at each sampling location was secured for analyses of BOD, solids fractions, nutrients and pH. Analyses were completed by the Chemistry Branch of the Commission. It should be noted that the chemical analyses given in this report are for single grab samples and that conditions obtained may not be representative. A more detailed sampling program has been carried out by the Water Quality Surveys Branch of the Division of Sanitary Engineering, and permanent monitoring stations are sampled regularly.

Presentation of data

As explained in the introduction, the survey being described was carried out to provide an indication of the overall health of the Grand River and its tributaries. Localized areas along the main branch of the Grand River are intensively industrialized. However, with the exception of the Canagagigue and Alder creeks, the survey was designed to evaluate general conditions throughout the watershed rather than to relate specific discharges to the results obtained.

To facilitate reference, the aquatic life of Canagagigue Creek, Conestogo River, Nith River, Upper Grand River, Middle Grand River and the Lower Grand River will be described separately in the above order.

CANAGAGIGUE CREEK

Changes in chemical characteristics and the composition of fish and bottom fauna communities of Canagagigue Creek are illustrated in Figure 1.

Bottom fauna at control stations Ca1, Ca2, Ca4 and Ca5 upstream from Elmira, as well as the unpolluted tributary station Ca12 near the mouth of the creek, contained an average of 18 taxa of macroinvertebrates per station. The variety of organisms at these stations was typical of unpolluted warm water streams in Southern Ontario. Some impairment of water quality was evident at station Ca6 located within Elmira but upstream from the major waste discharges. Fourteen taxa of macroinvertebrates consisting mainly of organisms semi-tolerant to pollution, but including the relatively intolerant mayflies (_Caenis_ and _Centroptilum_), were obtained at this station. A drastic reduction in the number of taxa to 4 was noted at station Ca7. The disappearance of 10 taxa of pollution-tolerant organisms indicated a critical change in the aquatic environment between stations Ca6 and Ca7. Immediately upstream from station Ca7, a small drainage ditch enters the creek. The ditch originates at the western boundary of Elmira, flows easterly through the town and finally passes adjacent to the chemical plant of Uniroyal 1966 Limited, where it receives cooling water discharges. The discharge of this

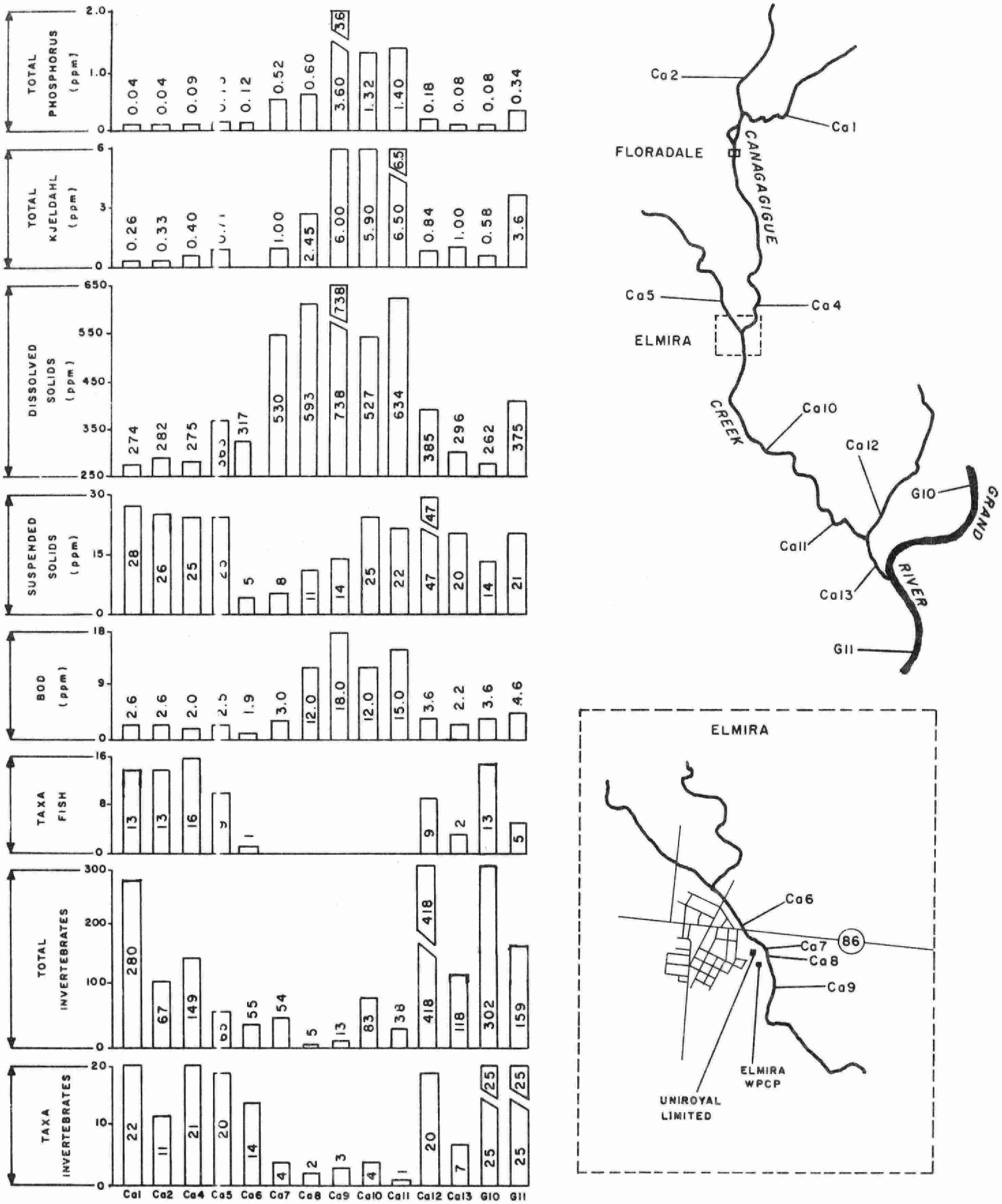

FIG. I BIOLOGICAL AND CHEMICAL CONDITIONS AT 15 STATIONS ON THE CANAGAGIGUE CREEK - GRAND RIVER IN JUNE, 1966.

stream into Canagagigue Creek appears to form a boundary between the relatively unaltered upstream waters and the heavily polluted waters below this point. The upstream section had the appearance of a normal unpolluted stream since fish were noted swimming amongst the rooted vegetation. Immediately below the discharge ditch and throughout the remainder of the creek, no fish were observed and the rooted vegetation gave way to profuse and unsightly periphytic growths of green algae, diatoms and flagellates.

At station Ca8, 100 feet downstream from station Ca7, the bottom fauna was altered more drastically towards fewer individuals and a reduced number of taxa. Only 4 individuals and 2 taxa of macroinvertebrates were obtained. A community of this nature in Southern Ontario is found only in the presence of considerable toxic pollution. Approximately 100 feet of earth separates the creek from retention lagoons operated by Uniroyal 1966 Limited. Seepage from these ponds probably occurs, thereby accounting for the unbalanced nature of the macroinvertebrate community at station Ca8. Similar conditions were evident at station Ca9, approximately 100 yards downstream from the Elmira Water Pollution Control Plant, and again at stations Ca10 and Ca11. At the latter station, approximately 2 miles downstream from Elmira, toxic conditions limited the bottom fauna to midge larvae (Chironomidae). Environmental conditions were improved considerably at the mouth of Canagagigue Creek (station Ca13) following dilution from the tribuatry stream at West Montrose. Seven taxa of macroinvertebrates including an intolerant mayfly (Paraleptophlebia) and caddisfly (Hydropsyche) were obtained. As at the upstream locations, midge larvae constituted the bulk of the bottom fauna community. Control station G10 on the Grand River and station G11 downstream from the influent of Canagagigue Creek each contained a varied bottom fauna of 25 taxa, indicating generally satisfactory conditions.

Twenty species of fish were collected from Canagagigue Creek. Generally, fish diversity and abundance were similar to that of the bottom fauna. Total removal of all fish present in a 150-foot section of the creek at control stations Ca1 and Ca2 produced an average of 848 fish and a total of 14 species. Fish were similarly abundant at control stations Ca4, Ca5, and Ca12. At

station Ca6, fewer fish than would be expected were obtained and the only species represented was the common shiner, (Notropis cornutus). All fish were excluded from the creek at and between stations Ca7 and Call. Some improvement in water quality was evident at station Cal3 where the white sucker (Catostomus commersoni) and the bluntnosed minnow (Pimphales notatus) were taken. Limited dilution occurs upstream from this station which would account for this improvement. However, a normal fish community was not present at that location and moreover, seven species of fish disappeared from the Grand River at station Gll, below the point of entry of Canagagigue Creek into the Grand.

From the headwaters to the mouth of Canagagigue Creek, extreme changes occurred in the chemical properties of the water. Generally these changes were similar in magnitude and location to the changes in the aquatic life in the creek. The headwaters downstream to station Ca6 revealed uniformly low concentrations of BOD, nutrients and dissolved solids. The reach between stations Ca7 and Call was characterized by extremely high concentrations for these same parameters. Downstream from the tributary at West Montrose, water of improved quality was evident.

Changes in the dissolved solids of the creek are closely related to the observed changes in the bottom faunal communities. Concentrations of dissolved solids averaged 300 ppm at the control stations. Below the discharge ditch between stations Ca6 and Ca7, the dissolved solids increased to 530 ppm (station Ca7) and 593 ppm at station Ca8 adjacent to the retention lagoons at Uniroyal 1966 Limited. Possibly toxic elements reach the creek from the drainage ditch and also by seepage from the lagoons.

Extremely high concentrations of nutrients were present in the creek below Elmira. Undoubtedly, Canagagigue Creek provides a significant and undesirable contribution to the nutrient budget of the Grand River.

CONESTOGO RIVER

Changes in chemical characteristics and the structure of fish and bottom fauna communities in the Conestogo River are illustrated in Figure 2.

Bottom fauna communities were examined at 6 locations on the Conestogo River. An average of 18 taxa of macroinvertebrates per station was collected from these locations. Included at each of the sampling stations C1 to C6 were representatives of the pollution-intolerant mayflies and caddisflies. Midge larvae (Chironomidae), sludgeworms (Oligochaeta), leeches (Hirudinea), and blackfly larvae (Similium), were present in low densities at one or more of the six sampling locations. When abundant, these forms indicate organic enrichment; however, their occurrence in low densities is typical of most healthy warmwater rivers in Southern Ontario.

Composition of the bottom fauna communities at station C1, C2 and C3 indicated that water quality above Conestogo Lake was not appreciably altered. However, levels of BOD detected at the same location provided evidence of organic contamination.

Both BOD and suspended solids concentrations were elevated at station C4 (below Glen Allen) downstream from Conestogo Lake, and the bottom fauna community at the same location provided further evidence of water quality impairment. Bottom fauna were represented by only 12 taxa. However, the presence of relatively intolerant mayflies (Ephemerella) and (Ephemera), damselflies (Enallagma) and a single caddisfly (Hydropsyche) indicated that the impairment was not severe.

The variety and abundance of mayflies and caddisflies at station C5 and C6 indicated the presence of unimpaired water.

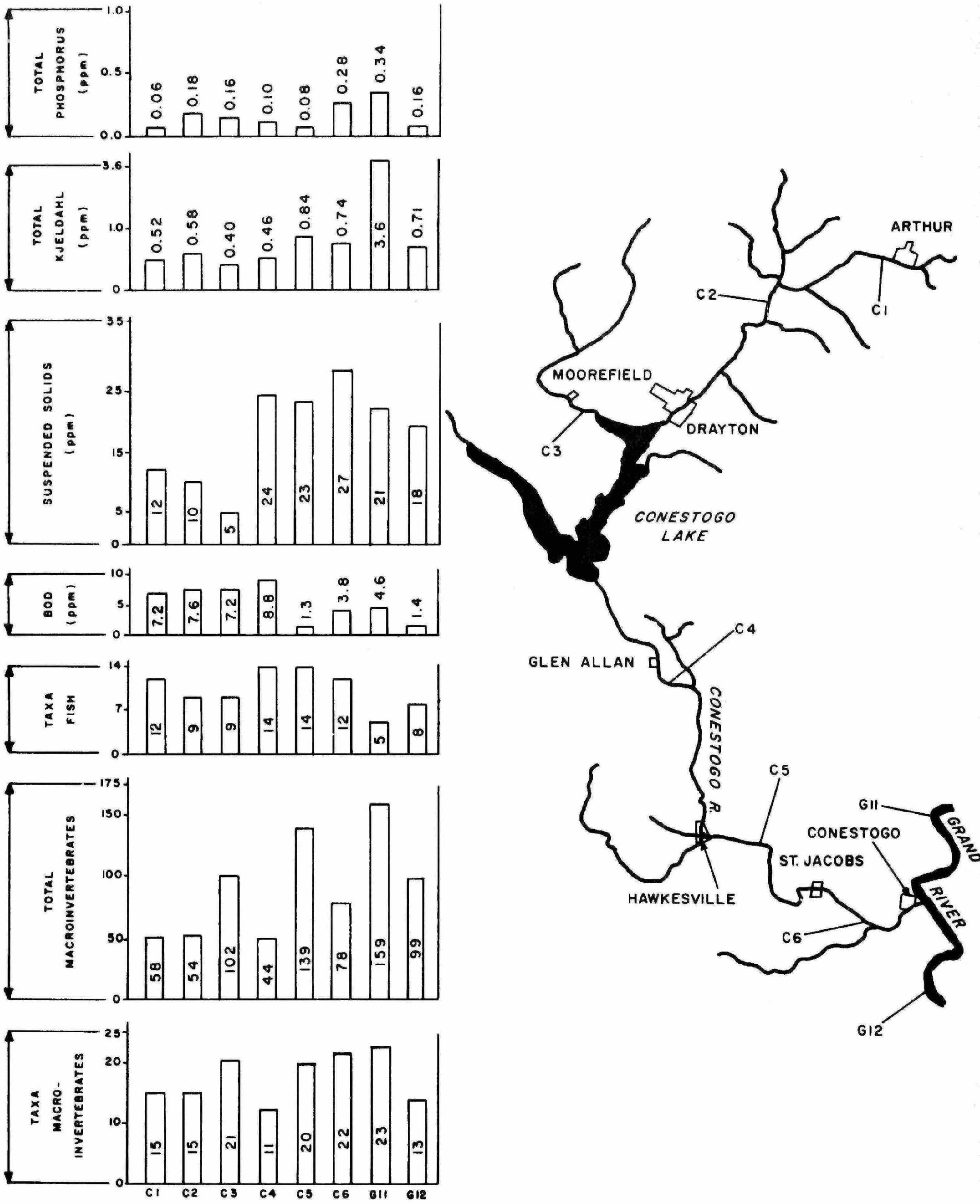

FIG. 2 BIOLOGICAL AND CHEMICAL CONDITIONS AT 8 STATIONS ON THE CONESTOGO RIVER AND GRAND RIVER IN JUNE, 1966.

Data on fish populations are in agreement with the preceding observations based on bottom fauna. Eighteen taxa of fish were collected from the Conestogo River. Species diversity appeared to be similar at all stations and provided no evidence of impaired water quality. Creek chubs (*Semotilus atromaculatus*), common shiners (*Notropis cornutus*), rosyface shiners (*Notropis rubellus*), white suckers (*Catostomus commersoni*), and rainbow darters (*Etheostoma caeruleum*), were present at all six sampling locations (stations C1 to C6). However, Conestogo Lake appeared to form a physical boundary limiting the distribution of 7 species. Two of the species, the redhorse sucker (*Moxostoma* sp) and blacknose dace (*Rhinichthys atratulus*) were obtained only above Conestogo Lake, while the river chub (*Hybopsis micropogon*), fathead minnow (*Pimephales promelas*), longnose daces (*Rhinichthys cataractae*), northern hog sucker (*Hypenthelium nigrican*) and fantail darter (*Etheostoma flabellare*) were present only below Conestogo Lake.

The only larger fish present in the Conestogo River appear to be three species of suckers, and the rock bass (*Ambloplites rupestris*).

NITH RIVER

Water chemistry and the structure of fish and bottom fauna communities at eleven locations on the Nith River watershed are illustrated in Figure 3.

Bottom fauna communities at the eleven sampling stations contained an average of 16 taxa of macroinvertebrates per station with a range between 11 taxa taken at the control station N1 and 20 taxa at station N4. The variety of organisms was typical of unpolluted warm water rivers in Southern Ontario and consisted almost exclusively of organisms either intolerant or semi-tolerant to organic pollution. The intolerant forms (i.e. mayflies, caddisflies and stoneflies) were well represented at all stations except N8 on Alder Creek. The only intolerant

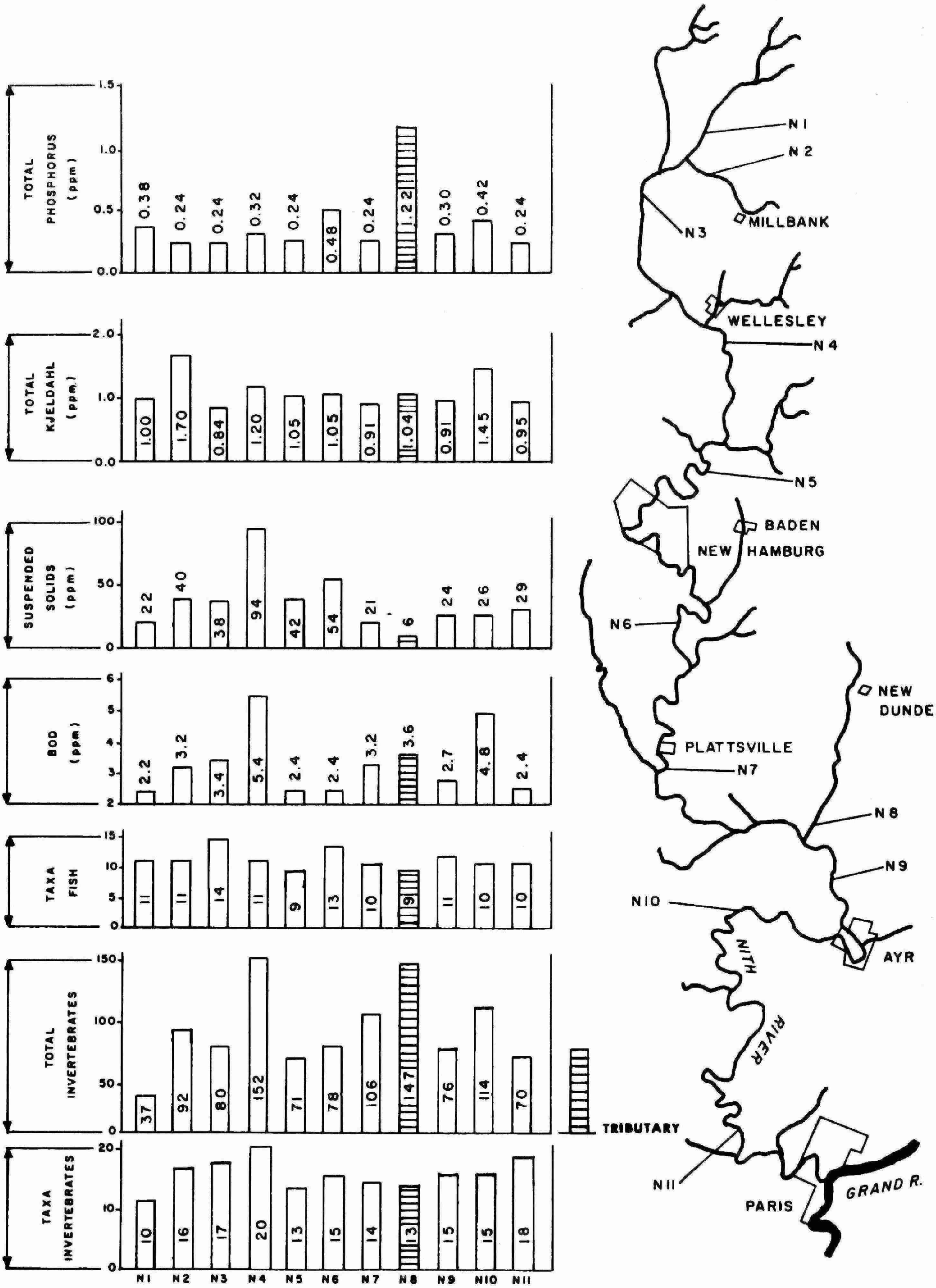

FIG. 3 BIOLOGICAL AND CHEMICAL CONDITIONS AT 11 STATIONS ON THE NITH RIVER IN JUNE, 1966.

organisms present at this station were single representatives of the mayfly Baetis and caddisfly Hydropsyche. Midge larvae (Chironomidae), blackfly larvae(Simulium), leeches(Erpobdellidae) and isopod (Asellus) were the most abundant organisms. Large standing crops of these organisms indicated considerable organic enrichment in Alder Creek. It is significant that high phosphate levels were encountered at the same station. Poultry processing wastes from Tend-R-Flesh Limited at Petersburg are discharged to the creek and are likely responsible for the alteration in water quality.

Baden Creek, a tributary flowing into the Nith River below New Hamburg, receives dairy wastes from Baden Cheese Limited. No study was made of Baden Creek during the 1966 biological survey. However, previous Commission reports have indicated that the water quality of Baden Creek is altered by these dairy wastes. Sampling at station N9 revealed no significant impact from the discharge of Baden Creek on the water quality in the Nith River.

Fish populations were reasonably uniform throughout the Nith River and provided no evidence of impaired water quality. The smallmouth bass (Micropterus dolomieui), an important game fish, appeared to be common throughout the river. Other fish of interest to the sport fishery of the Nith River included the rock bass(Ambloplites rupestris), and yellow perch (Perca flavescens).

Chemical analyses of the water in the Nith River indicated only minor modifications of water quality, with increased BOD concentrations below Wellesley and Ayr. More intensive biological and chemical sampling would undoubtedly define more clearly whether or not significant localized pollution exists downstream from the larger centres.

UPPER GRAND RIVER

Chemical properties and the structure of fish and bottom fauna communities in the Upper Grand River are illustrated in Figure 4.

Bottom fauna indicated definite impairment of water quality at station G1 below Dundalk. Organisms with little resistance to organic pollution were limited in both diversity and abundance. Only 5 individuals representing 4 taxa of intolerant mayflies and caddisflies were obtained during the timed collection at station G1. At control station G2 on a nearby tributary, identical sampling procedures produced 74 organisms representing 6 taxa of mayflies and caddisflies. A varied and well-balanced community of macroinvertebrates was secured at station G3. At that point, recovery from the upstream pollution had taken place. Macroinvertebrates present at station G4 above Grand Valley, station G5 below Grand Valley and station G6 below the village of Waldemar were remarkably similar to the clean water community present at station G3. No impairment of water quality was evident at any of those locations. Timed collections of bottom fauna at station G7, G8 and G10 contained 21, 11 and 25 taxa of macroinvertebrates respectively. A toxic environment was indicated by the bottom fauna at station G8 below Fergus. The community was altered both quantitatively and qualitatively towards fewer numbers than were present at the upstream location G7.

Biological data indicated that water of satisfactory quality was present at station G10 below Elora, G11 below the entry of Canagagigue Creek and G12 below the entry of the Conestogo River.

Impairment of water quality was evident from the fish obtained at stations G8 and G11. At the former location, below Fergus, five seine hauls yielded a poor catch containing

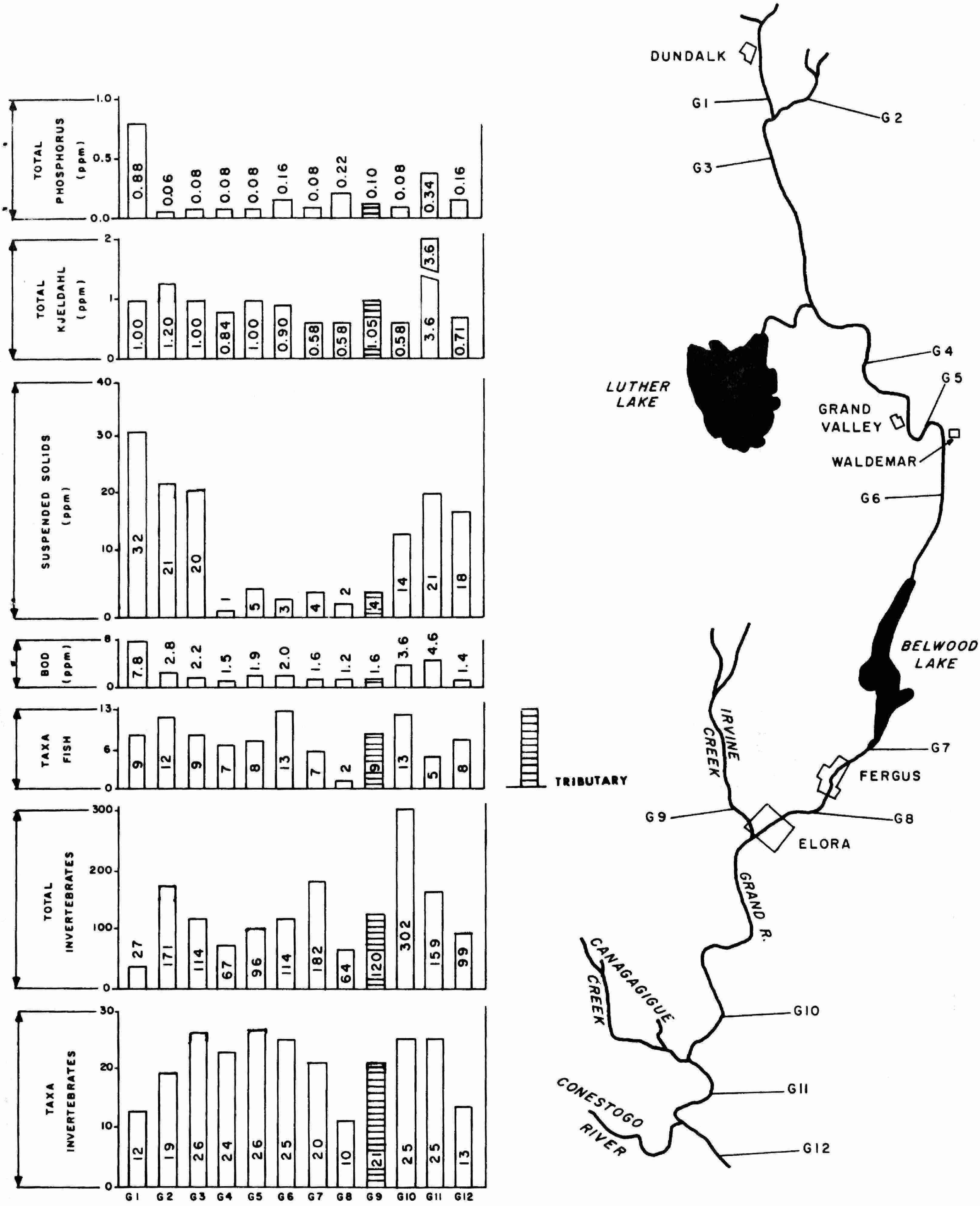

FIG. 4 BIOLOGICAL AND CHEMICAL CONDITIONS AT 12 STATIONS ON THE UPPER GRAND RIVER IN JUNE, 1966.

only the pollution-tolerant blacknose dace. At station G11 seven species of fish disappeared as a result of toxic wastes from Canagagigue Creek.

Chemical properties of the water at station G1 indicated considerable enrichment, as did the bottom fauna. The highest concentrations of BOD and suspended solids in this section of the river were found at this point. On the basis of one set of samples, water chemistry at station G8 would not account for the unbalanced nature of the aquatic communities at that location. Nonetheless, biological conditions indicate that impairment has taken place. The influence of impaired water from Canagagigue Creek was detected chemically at station G11 on the Grand River. At that location, the level of BOD, nutrients and solids increased.

MIDDLE GRAND RIVER

Changes in chemical properties and the structure of fish and bottom fauna communities in the Middle Grand River are illustrated in Figure 5.

Bottom fauna of the Grand River from Bridgeport to Brantford remained fairly uniform. Mayflies and caddisflies, which as a group are relatively intolerant to organic pollution, were represented at each station (G12 to G20). However, a notable decrease in both density and variety of these cleanwater forms below station G12(control), combined with a substantial representation of the relatively tolerant midge larvae(Chironomidae), sowbugs (Asellus), amphipods (Hyallela), blackflies (Simulium) and leeches (Moorebdella and Nephelopsis), indicated organic enrichment and a reduction in water quality throughout the entire Middle Grand River.

Further indication of considerable enrichment was provided by the profuse periphytic growths of algae below Kitchener-Waterloo and the complete blanket of green algae (Cladophora) which choked the entire river between Galt and Brantford.

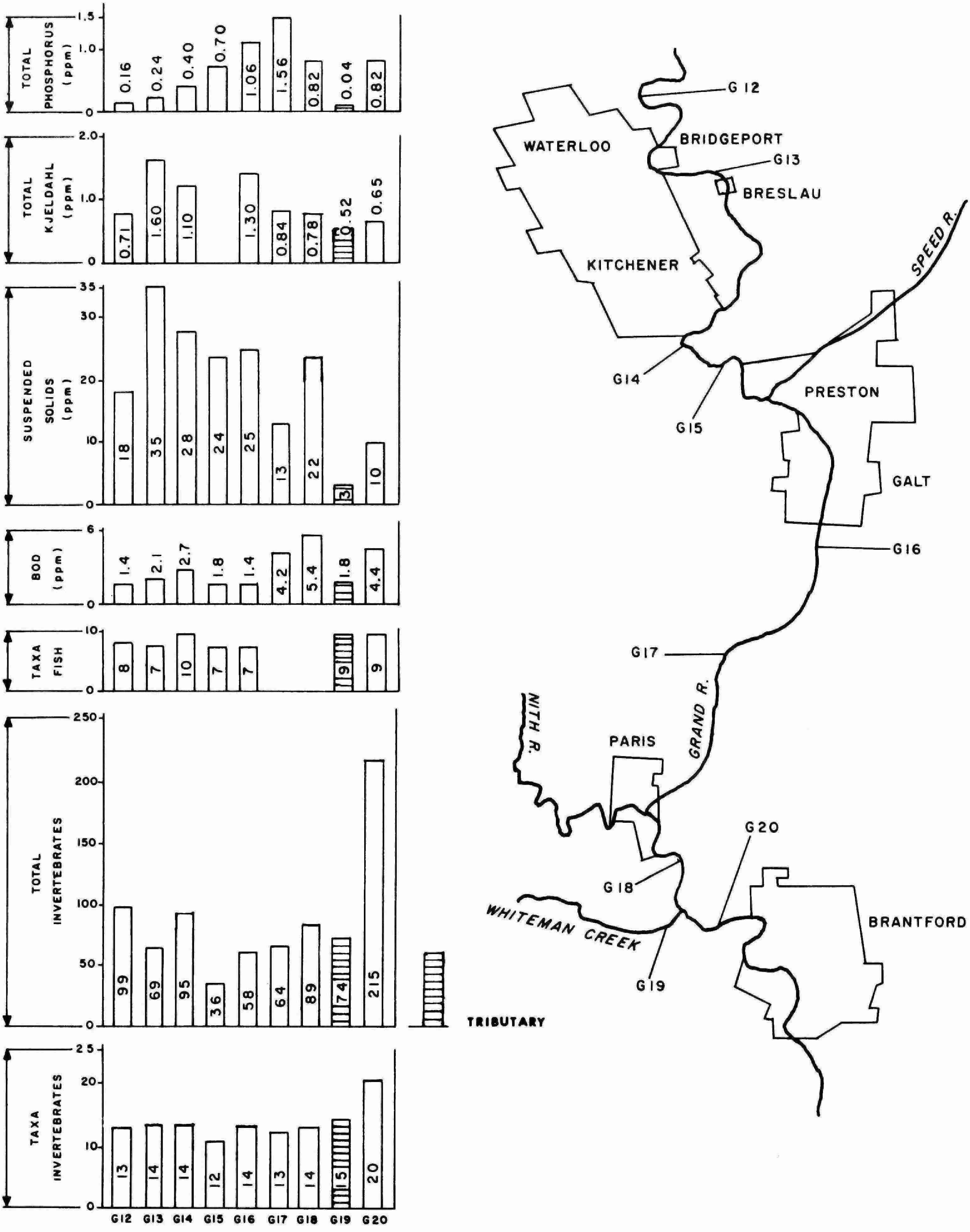

FIG. 5 BIOLOGICAL AND CHEMICAL CONDITIONS AT 9 STATIONS ON THE MIDDLE GRAND RIVER IN JUNE, 1966.

Chemical analyses substantiated the aforementioned indications of enrichment below Kitchener-Waterloo, below Galt and below Paris. Total phosphorus reached a peak high of 1.5 ppm at station G17 below Galt. BOD levels were elevated at stations G14, G17 and G18, indicating separate contributions below Kitchener-Waterloo, Galt and Paris.

No fishing was attempted at stations G17 and G18. The remaining stations contained a variety of warm water species, and the pollution-tolerant carp (Cyprinus carpio) and the white sucker (Catostomus commersoni) formed the bulk of the catch. These fish are capable of withstanding low concentrations of dissolved oxygen and can survive in water of poor quality.

LOWER GRAND RIVER

Chemical properties and the structure of fish and bottom fauna communities in the Lower Grand River are illustrated in Figure 6.

Timed qualitative sampling procedures were employed at station G20 above Brantford and stations G21 and G22 below Brantford. A marked decrease in variety and abundance of organisms indicated considerable impairment of water quality below this city. Enrichment resulting from waste inputs at Brantford was detectable downstream to stations G24 and G26. Five Ekman-dredge samples of the sediments at those locations yielded large numbers of tolerant midge larvae (Chironomidae) and sludgeworms (Tubificidae). Some improvement in water quality was evident below Caledonia (station G27) where a timed qualitative sample of the bottom fauna secured 19 taxa of macroinvertebrates, including an intolerant mayfly (Baetis), caddisfly (Cheumatopsyche) and damselflies (Agrion and Argia). Similar sampling procedures at station G29 below Cayuga indicated water of comparable quality to that of the upstream station G27. Both mayflies and caddisflies were obtained. Considerable impairment of water quality was evident at station G30 (below Dunnville), where dredge samples secured only pollution-tolerant midge larvae, sludgeworms and

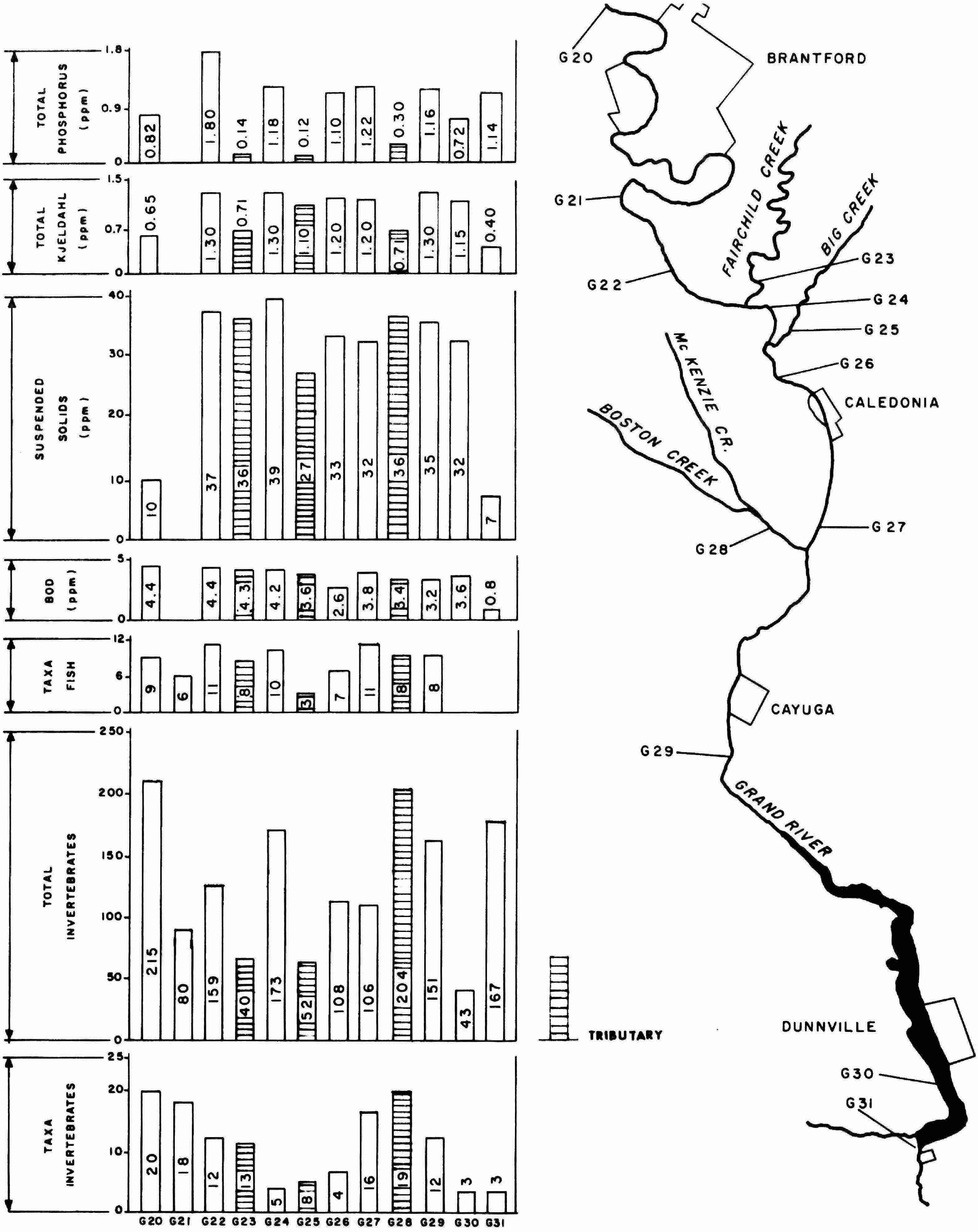

FIG. 6 BIOLOGICAL AND CHEMICAL CONDITIONS AT 12 STATIONS ON THE LOWER GRAND RIVER IN JUNE, 1966.

corixid bugs. No improvement was evident at Port Maitland at the mouth of the Grand River. The only additional taxa secured at that location (station G31) was the semi-tolerant sowbug (Asellus).

While bottom fauna indicated the presence of impaired water quality below Brantford and Dunnville, qualitatively the fish communities of the Lower Grand River did not appear to be altered towards undesirable species. A variety of game fish were secured. These included largemouth bass, smallmouth bass, pike, brown bullhead, rock bass, pumpkinseed, and suckers.

Moderately high standing crops of phytoplankton below Brantford (3,114 a.s.u. per ml.) and at the mouth of the Grand River (5,526 a.s.u. per ml.) indicated considerable aquatic enrichment. Chemical analyses verified this fact. Peak nutrient concentrations were detected below Brantford, Caledonia and Cayuga. Average values obtained for total phosphorus and total nitrogen were 1.19 ppm and 1.12 ppm for the seven sampling locations on the Lower Grand River. Nutrient concentrations of that magnitude are sufficient to promote algal blooms and undoubtedly the nutrients carried in the Lower Grand River have a profound effect on the littoral zone of Lake Erie at the mouth of the Grand River.

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APPENDIX

Table 1.	Macroinvertebrates collected at 13 stations on Canagagigue Creek, 1966. Collecting methods are outlined in the text of the report.
2.	Catches of fish taken at 13 stations on the Canagagigue Creek in June, 1966. Stations Ca1, Ca2 and Ca12 were sampled by electrofishing. A beach seine was used at all other stations.
3.	Results of chemical analyses on samples collected at 13 stations on Canagagigue Creek. Samples Ca1 to Ca5 and Ca10 to Ca13 were collected in June, 1966. Samples Ca6 to Ca9 were collected in September, 1966.
4.	Macroinvertebrates collected at 6 stations on the Conestogo River in June, 1966. Collecting methods are outlined in the text of the report.
5.	Catches of fish made by seining at 6 stations on the Conestogo River in June, 1966.
6.	Results of chemical analyses on samples collected at 6 stations on the Conestogo River in June, 1966.
7.	Macroinvertebrates collected at 11 stations on the Nith River in June, 1966. Collecting methods are outlined in the text of the report.
8.	Catches of fish made by seining at 11 stations on the Nith River in June, 1966.
9.	Results of chemical analyses on samples collected at 11 stations on the Nith River in June, 1966.
10.	Macroinvertebrates collected at 31 stations on the Grand River in June, 1966. Collecting methods are outlined in the text of the report.
11.	Catches of fish taken at 27 stations on the Grand River in June, 1966. Fish were taken with a seine net. No fish were collected at stations G17 and G18.
12.	Results of chemical analyses on samples collected at 30 locations on the Grand River in June, 1966.

Table 1. Macroinvertebrates collected at 12 stations on the Canagagigue Creek in June, 1966. Collecting methods are outlined in the text of the report.

	Ca1	Ca2	Ca4	Ca5	Ca6	Ca7	Ca8	Ca9	Ca10	Ca11	Ca12	Ca13
STONEFLIES												
Acroneuria		1										
MAYFLIES												
Caenis	3	2	8		6							
Baetis	14	5		1							11	
Centroptilum					1							
Paraleptophlebia	4			6							7	1
Ephemerella	2		8									
Stenonema	5	1	1								14	
CADDISFLIES												
Hydropsychidae	79		2								234	1
Neophylax	3											
Chimarra	1											
Pychnopsyche	2	1		1							5	
Hydroptila	1											
Wormaldia		1										
Asynarchus											1	
CRANEFLIES												
Tipulidae											1	
Antocha	8											
DIPTERA												
Ephydra								6				
Chrysops												1
Simulium	1	46	1	9	1	8					1	
Chironomidae	70	7	56		26	9	4	6	78	38	96	97
DAMSELFLIES												
Enallagma			6	1								
Ischnura					1				1			
BEETLES												
Agabus				2								
Berosus							1					
Adults	8			6	1						3	10
BUGS												
Corixidae	4		7	13					1			4
CRAYFISH												
Orconectes	6		8	3							5	
SCUDS												
Hyalella	1	1	31	8	1						1	
Crangonyx												4

Table 1. (continued)

	Ca1	Ca2	Ca4	Ca5	Ca6	Ca7	Ca8	Ca9	Ca10	Ca11	Ca12	Ca13
MOLLUSCS												
Unionidae		1	1									
Sphaerium	69		14	3							6	
Pisidium			1	1							2	
Physa	3		1	1	2	30					3	
Helisoma			1									
Gyraulus				1	1							
Lymneae					1			1			1	
WORMS												
Naididae			5									
Tubificidae			5	1	1	8					25	
Lumbriculidae				2					1			
LEECHES												
Erpobdellidae			2	3	9						2	
C. *complanata*			1		2							
Haemopsis				1								
H. *stagnatis*					2							

Table 2. Catches of fish taken at 13 stations on the Canagagigue Creek in June, 1966. Stations Ca1, Ca2 and Ca13 were fished electrically. A beach seine was used at all other stations.

	Ca1	Ca2	Ca3	Ca4	Ca5	Ca6	Ca7	Ca8	Ca9	Ca10	Ca11	Ca12	Ca13
Hornyhead chub	P	P	P	P	P								
Creek chub	P	P		P								P	
River chub				P									
Brassy minnow				P	P							P	
Bluntnose minnow	P	P	P	P	P							P	P
Fathead minnow	P	P	P	P	P							P	
Common shiner	P	P	P	P	P	P						P	
Longnose dace				P									
Blacknose dace	P	P		P								P	
Northern red-belly dace					P								
Pearl dace	P												
White sucker	P	P	P	P	P							P	P
Northern hog sucker				P									
Rainbow darter	P	P	P	P									
Fantail darter	P	P		P								P	
Johnny darter	P	P	P	P									
Least darter				P	P								
Rock bass	P	P	P	P									
Brook stickleback		P			P								
Mottled sculpin	P	P										P	

Table 3. Results of chemical analyses made on samples collected at 13 stations on the Canagagigue Creek. Samples Ca1 to Ca5 and Ca10 to Ca13 were collected in June, 1966. Samples Ca6 to Ca9 were collected in September, 1966.

Station	BOD	SOLIDS Susp.	Diss.	Free Ammonia	Total Kjeldahl	Total Phosphorus
Ca1	2.6	28	274	Tr.	0.26	0.04
Ca2	2.6	22	282	Tr.	0.33	0.04
Ca3	2.0	32	300	0.06	0.40	0.06
Ca4	2.0	25	275	0.05	0.40	0.09
Ca5	2.4	25	363	0.12	0.71	0.15
Ca6	1.9	5	317	0.39	-	0.12
Ca7	3.0	8	530	0.26	1.00	0.52
Ca8	12.0	11	593	0.57	2.45	0.60
Ca9	18.0	14	738	3.61	6.00	3.60
Ca10	12.0	25	527	1.24	5.90	1.32
Ca11	15.0	22	634	5.80	6.50	1.40
Ca12	3.6	47	385	Tr.	0.84	0.18
Ca13	2.2	20	296	0.06	1.00	0.08

Table 4. Macroinvertebrates collected at 6 stations on the Conestoga River in June, 1966. Collecting methods are outlined in the text of the report.

	C1	C2	C3	C4	C5	C6
MAYFLIES						
Caenis	9	6			8	3
Centroptilum					1	
Baetis	3					1
Ephemerella		3	18	2	16	1
Ephemera				7	2	1
Stenonema	1	6	4		46	16
CADDISFLIES						
Triaenodes	1		1			
Hydropsyche	4		2	1	23	1
Cheumatopsyche	14		1		6	6
Helicopsyche			1			3
Pycnopsyche						1
DRAGONFLIES						
Gomphus		2	1			
DAMSELFLIES						
Ischnura			3			
Enallagma	4	11		9		12
Agrion						3
FLIES						
Chironomidae	3	5	8	6	6	2
Simulium	3					
Chrysops		2				1
Tipula					1	
Cataclysta					1	
BEETLES						
Psephenus		1	1		1	
Stenelmis					1	2
Adults	1	4	10	2	3	
AMPHIPODS						
Hyalella	7	1	20			3
CRAYFISH						
Orconectes		3	2		13	6
MITES						
Unidentified			8			
MOLLUSCS						
Physa			2	10	4	2
Helisoma	3					
Valvata			2			
Lymnaea				1		
Pleurocera					1	5
Ferrisia						1
Pisidium		1	4	1		2
Sphaerium	1		8		1	5

Table 4. (continued)

	C1	C2	C3	C4	C5	C6
BUGS						
Corixidae	2	6	3	4	2	
WORMS						
Lumbriculidae			12	1	2	
Tubificidae		1				1
LEECHES						
Erpobdellidae	2	2			1	
Helobdella			1			

Table 5. Catches of fish made by seining at 6 stations on the Conestoga River in June, 1966.

	C1	C2	C3	C4	C5	C6
Hornyhead chub	P		P	P	P	P
Creek chub	P	P	P	P	P	P
River chub				P	P	P
Brassy minnow	P	P	P	P	P	
Bluntnose minnow		P	P	P	P	P
Fathead minnow				P	P	
Common shiner	P	P	P	P	P	P
Roseface shiner	P	P	P	P	P	P
Longnose dace					P	
Blacknose dace	P					
Northern hog sucker				P	P	P
White sucker	P	P	P	P	P	P
Redhorse sucker	P					
Rainbow darter	P	P	P	P	P	P
Fantail darter				P	P	P
Blackside darter	P					P
Johnny darter	P	P		P	P	
Rock bass	P	P	P	P		P

Table 6. Results of chemical analyses made on samples collected at 6 stations on the Conestoga River in June, 1966.

Station	BOD	SOLIDS Susp.	SOLIDS Diss.	pH	Free Ammonia	Total Kjeldahl	Total Phosphorus
C1	7.2	12	398	-	Tr.	0.52	0.06
C2	7.6	10	278	-	Tr.	0.58	0.18
C3	7.2	5	293	-	Tr.	0.40	0.16
C4	8.8	24	286	-	Tr.	0.46	0.10
C5	1.3	23	269	8.4	0.03	0.84	0.08
C6	3.8	37	263	8.5	0.20	0.78	0.28

Table 7. Macroinvertebrates collected at 11 stations on the Nith River in June, 1966. Collecting methods are outlined in the text of the report.

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
STONEFLIES											
Perlesta		3		1							
Acroneuria							1				2
Neoperla											2
MAYFLIES											
Caenis	8	3	8	12	17		20		6	2	1
Baetis		16	7	13	1	8	5	1	1	3	
Stenonema		1	2	3	11	6	11				
Ephemera				2	10						
Hexagenia									13		
Ephoron											1
Potamanthus											3
CADDISFLIES											
Cheumatopsyche		25	7	14	3	2	4				
Hydropsyche		13	5	11		10	7	1			12
Pycnopsyche			2								
Triaenodes				1							
Chimarra											2
Leptocella											4
DAMSELFLIES											
Ischnura	1						4				
Enallagma	1	1	4	10	4	2	15		9	13	5
DRAGONFLIES											
Dromogomphus				1							
Boyeria									1		
FLIES											
Palpomyia			1								
Simulium		1	7	3	1	7		35			
Limnophora								1			
Chrysops		1									
Chrionomidae	17	11	9	34	12	10	21	28	11	29	5
BUGS											
Corixidae				1	1	1			6	3	1
Gerridae											1
BEETLES (adults)											
Unidentified			5	20	8	1	12	1	6	5	3
BEETLES Larvae											
Oreodytes		1	1								
Gyrinus					1						
Dytiscus									1	1	
Laccobius										1	

Table 7. (continued)

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
AMPHIPODS											
Hyalella	1	1	1		1	3	1	2	9	8	
ISOPODS											
Asellus								39	6		
CRAYFISH											
Cambarus	1										
Orconectes		3	2	4	1	5	3	1	3	7	4
MOLLUSCS											
Sphaerium			12	16		15				4	3
Pisidium								1			
Helisoma			1							3	1
Physa				2			1		2	20	1
Pleurocera				2						14	19
Amnicola									1	1	
WORMS											
Tubificidae	4	3						2			
Lumbriculidae	2	2	6			1	1	2			
LEECHES											
Erpobdellidae				1		6		33	1		
Helobdella	1	7									
Placobdella	1			2		1					

Table 8. Catches of fish made by seining at 11 stations on the Nith River in June, 1966.

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
Hornyhead chub	P	P	P	P	P	P	P	P	P	P	
Creek chub	P	P	P	P		P	P	P		P	P
River chub		P	P			P	P				
Brassy minnow									P		
Bluntnose minnow	P	P		P	P	P	P		P	P	P
Fathead minnow	P		P					P			
Common shiner	P	P	P	P	P	P	P	P	P	P	P
Golden shiner								P			
Roseface shiner	P	P	P	P	P	P	P			P	P
Spottail shiner				P							
Mimic shiner									P		
Northern redbelly dace						P					
Blacknose dace								P			
Longnose dace								P		P	
Carp						P				P	
Brook stickleback	P			P				P			
Northern hog sucker		P				P	P			P	P
Redhorse sucker		P		P		P	P		P	P	P
White sucker	P	P	P		P			P	P		P
Longnose sucker			P								
Rainbow darter	P	P	P	P		P	P			P	
Fantail darter	P			P			P				
Least darter	P		P								
Blackside darter			P		P				P		P
Johnny darter			P	P	P				P		P
Yellow perch									P		
Rock bass		P	P		P	P			P		
Smallmouth bass			P		P	P					P

Table 9. Results of chemical analyses made on samples collected at 11 stations on the Nith River in June, 1966.

Station	BOD	SOLIDS Susp.	Diss.	pH	Free Ammonia	Total Kjeldahl	Total Phosphorus
N1	2.4	22	294	7.4	0.03	1.00	0.38
N2	3.2	40	328	8.1	0.13	1.70	0.24
N3	3.4	38	332	8.0	0.03	0.84	0.24
N4	5.4	94	314	7.9	0.05	1.20	0.32
N5	2.4	42	368	8.3	0.08	1.05	0.24
N6	2.4	54	356	8.3	0.05	1.05	0.48
N7	3.2	21	347	8.0	0.16	0.91	0.24
N8	3.6	6	438	7.9	0.53	1.04	1.22
N9	2.7	24	382	7.7	0.16	0.91	0.30
N10	4.8	26	382	7.1	0.13	1.45	0.42
N11	2.4	29	375	8.0	0.02	0.91	0.24

Table 10. Macroinvertebrates collected at 31 stations on the Grand River in June, 1966. Collecting methods are outlined in the text of the report.

	STONEFLIES			MAYFLIES												CADDISFLIES												
	Isoperia	Acroneuria	Togoperla	Caenis	Tricorythodes	Baetis	Ephemerella	Paraleptophlebia	Leptophlebia	Ephemera	Arthroplea	Stenonema	Heptagenia	Potamanthus	Centroptilum	Leptocella	Neureclipsis	Polycentropus	Anabolia	Pycnopsychelepida	Pycnopsyche sp.	Trianodes	Cheumatopsyche	Hydropsyche	Chimarra	Platycentropus	Athripsodes	Mystacides
G1				1		1		1											2									
G2				1		1	56				2									1		8	5					
G3	3					1	16				1											1	30	10	5			
G4		2		1		1	2					15	2		1					2	1		2	2				
G5		1		1		2	3		1			22	3										2	1			1	
G6		3		2		13	6					21	6							11			1					1
G7				1		4						1												38				
G8				11					3															1				
G9			1	39		8	10	1				6											4	2				
G10						5	12					28								5	3	2	2	21		1		1
G11				4		4	4			2		5										18					1	
G12				4	1	11	1			2		22											1					
G13				23		2						13		3				1										
G14						1						2											1	1				
G15				3		1						6																
G16				1		3						8																
G17						9						3											4					
G18						2						2											21	4				
G19			5	1	2			1		1		27																
G20						5	2					15				1							24					
G21												5				2	1						4					
G22												1																
G23																												
G24																												
G25																												
G26																												
G27						1																	11					
G28				12								19								2			20					
G29					4											3												
G30																												
G31																												

Table 10. (continued)

	Rhyacophila	Psychomyia	Micrasema	Neophylax	Helicopsyche	Oecetis	Wormaldia	DAMSELFLIES	Ischnura	Enallagma	Agria	Agrion	DRAGONFLIES	Boyeria	Gomphus	FISHFLIES	Chauliodes	Antocha	Tipula	Chrysops	Palpomyia	Simulium	Chironomidae	BEETLES	Psephenus	Ectoparia	Optioservus	Agabus
G1										15				1								1	10					
G2									12	5				1	1								30					
G3									2	1												6	8		1	1		
G4											3												10		5		1	
G5									2	9											1		10		1			1
G6	1								2	7	2												2		5	1		1
G7	13	1	2																				62				1	
G8																							6					
G9	3			1	2		1												1				22		1			
G10									3									2					88			1		
G11	1	2	1						8	11		2										39	37					
G12					1					1												6	11		1			
G13						1																	11					
G14																						2	22			1		
G15																						1	13			1		
G16																						3	5			1		
G17																						4	10			3		
G18																						18	16		5			
G19	1																2	1					23		1			
G20																						43	12		4			
G21										1	2											1	14					
G22																							70					
G23										7											2		5					
G24																							144					
G25										1													8					
G26																							93					
G27										6	1												30					
G28										1	1									1			10					
G29									2	1													16					
G30																							8					
G31																							13					

Table 10. (continued)

	Ordobrevia	Galerucella	Dubiraphia	Stenelmis	Berosus	Laccophilus	Gyrinus	Unidentified adults	BUGS	Corixidae	Gerridae	Velidae	Ranatra	ISOPODS	Asellus	AMPHIPODS	Gammarus	Hyalella	Crangonyx	CRAYFISH	Orconectes	Cambarus	MOLLUSCS	Unionidae	Pisidium	Sphoerium	Physa	Lymnaea	Helisoma	Gyraulus	Valvata
G1								5										1	1		2						1	1			
G2								8		11														1			9		2	1	
G3								3		3											2					2	3			1	3
G4								1		3								2			3	1			3	1					
G5								3		3								13			2				3	5	1	1		1	
G6								3		6								6			6	1			6	3					
G7	1									10								31	1		4	2			3	1	5		2	1	
G8								12										21			6										
G9	1							6										8								1					
G10								1		93	3							10			2					3					
G11								2										6			2	2				1	3				
G12																															
G13		2	1					1										4			4										
G14				1				16							3												1				
G15								1		1								1													
G16								2							19			4	1							5					
G17								1							9			4			3					4					
G18								1							1			3			1						1				
G19								4													2	1									
G20	3			1											8			30							3	27	2				
G21				1	1					7											4					12	1				
G22						1		32										1			5					3	7				
G23						1				12	1							4			5					2	1				
G24								1		4																1					
G25							6	24		4	1	1						7													
G26																								1							
G27						3				1					1			14			3					5	11				
G28										4							2	4			6	1				83	2				3
G29								4					1				10	104								1					
G30								3																							
G31															1																

Table 10. (continued)

	Pleurocera	Amnicola	Campeloma	**MITES**	Unidentified	**FLATWORMS**	Curtisia	**WORMS**	Lumbriculidae	Tubificidae	**LEECHES**	Helobdella	Moorebdella	Nephelopsis	Erpobdellidae
G1															
G2					2					5					
G3					1				1						
G4					2										
G5									2						
G6									1						
G7										1					
G8										1		1	2		
G9					1				1			1			
G10	12								1			3			
G11									1						1
G12													4	35	
G13												1	2		
G14										2			1	41	
G15										1			3	4	
G16					1					1				4	
G17										1				9	
G18	9													5	
G19	2														
G20	16						1					1	4	13	
G21	10						1			5		1		14	
G22	26											1		5	
G23															
G24										23					
G25															
G26										13			1		
G27	10						3			1			5		
G28	19	3	11												
G29					3					2					
G30										32					
G31										153					

Table 11. Catches of fish taken at 27 stations on the Grand River in June, 1966.

	Hornyhead chub	Creek chub	River chub	Brassy minnow	Fathead minnow	Bluntnose minnow	Roseface shiner	Common shiner	Mimic shiner	Spotfin shiner	Golden shiner	Blacknose dace	Pearl dace	Longnose dace	Northern redbelly dace	Carp	White sucker	Northern hogsucker	Killifish	Mottled sculpin	Brook stickleback	Fantail darter	Rainbow darter	Least darter	Johnny darter	Log perch	Walleye	Yellow perch	Rock bass	Pumpkinseed	Smallmouth bass	Largemouth bass	Tadpole madtom	Brown bullhead	Brook trout	Pike
G1		P		P	P			P				P	P		P		P				P															
G2		P		P	P	P		P				P	P		P				P		P	P							P							
G3	P	P			P			P				P			P				P			P							P							
G4	P	P	P					P				P		P								P														
G5	P	P		P				P				P							P			P						P								
G6	P	P	P	P	P	P		P				P		P			P					P						P	P							
G7								P				P		P	P					P	P							P								
G8												P																								
G9	P	P	P			P		P				P					P	P					P						P							
G10	P	P	P			P	P	P				P					P						P	P	P				P							
G11	P				P	P	P	P																												
G12		P				P	P	P						P		P	P								P											
G13		P				P	P	P						P		P									P											
G14		P		P	P	P		P						P	P	P	P				P															
G15		P				P	P	P				P		P			P																			
G16		P			P	P		P						P		P	P																			
G19		P						P				P		P			P	P					P		P										P	
G20			P			P		P						P			P	P					P										P			
G21						P			P	P							P									P			P							
G22						P			P	P	P						P								P	P			P	P	P	P				
G23						P			P								P								P		P		P		P					P
G24						P			P	P	P						P								P	P			P	P		P				
G25																													P	P		P				
G26						P			P								P						P		P				P				P			
G27			P			P		P	P								P								P				P	P	P	P		P		
G28	P		P				P	P									P												P		P			P		
G29						P				P							P									P			P	P	P			P		

Table 12. Results of chemical analyses made on samples collected at 30 locations on the Grand River in June, 1966.

		SOLIDS			Free	Total	Total
Station	BOD	Susp.	Diss.	pH	Ammonia	Kjeldahl	Phosphorus
G1	7.8	32	320	-	0.05	1.00	0.88
G2	2.8	21	301	-	0.05	1.20	0.06
G3	2.2	20	296	-	0.06	1.00	0.08
G4	1.5	1	303	8.3	0.05	0.84	0.08
G5	1.9	5	327	8.4	0.05	1.00	0.08
G6	2.0	3	315	8.3	0.03	0.90	0.16
G7	1.6	4	256	8.1	0.02	0.58	0.08
G8	1.2	2	282	8.6	0.03	0.58	0.22
G9	1.6	4	324	8.3	0.02	1.05	0.10
G10	3.6	14	262	-	0.10	0.58	0.08
G11	4.6	21	375	-	0.60	3.60	0.34
G12	1.4	18	294	8.8	0.13	0.71	0.16
G13	2.1	35	303	8.2	0.13	1.60	0.24
G14	2.7	28	312	8.6	0.13	1.10	0.40
G15	1.8	24	370	8.6	0.40	-	0.70
G16	1.4	25	365	8.6	0.16	1.30	1.06
G17	4.2	13	387	8.0	0.05	0.84	1.56
G18	5.4	22	466	8.3	0.16	0.78	0.82
G19	1.8	3	495	8.4	0.10	0.52	0.04
G20	4.4	10	4.50	8.3	0.13	0.65	0.82
G22	4.4	37	419	8.5	0.39	1.30	1.80
G23	4.2	36	438	8.1	0.05	0.71	0.14
G24	4.2	39	401	8.1	0.43	1.30	1.18
G25	3.6	27	323	7.8	0.23	1.10	0.12
G26	2.6	33	437	8.4	0.33	1.20	1.10
G27	3.8	32	418	8.3	0.30	1.20	1.22
G28	3.4	36	920	8.0	0.13	0.71	0.30
G29	3.2	35	471	8.8	0.02	1.30	1.16
G30	3.6	32	500	8.1	0.36	1.15	0.72
G31	0.8	7	289	8.1	0.23	0.40	1.14